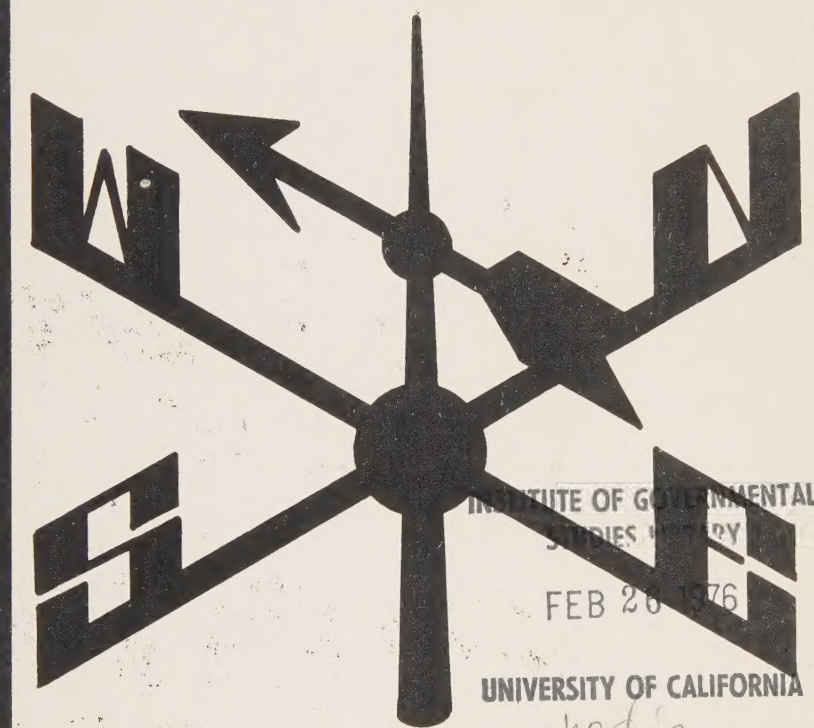


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City of Torrance Planning Department

ENVIRONMENTAL DIVISION
CITY OF TORRANCE
PLANNING DEPARTMENT
JULY, 1975

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introduction


While reading this report, the difference between weather and climate should be kept in mind. The momentary state of the atmosphere we call weather, its long term state is climate. Climate is not strictly an average of the weather as such, but a statistical representation of significant weather events in terms of either frequency or intensity.

In looking at the climate of a small area such as the City of Torrance, there are three distinct facets which must be considered:

- (1) The general hemispheric circulation patterns determined by oceans, continents and latitude as they pertain to the area under study.
- (2) The regional modifications of the general circulation created by large scale physical features, e.g., mountain ranges, very large bodies of water, etc.
- (3) The localized affects created in a specific location by small scale geographic differences, e.g., the differences between valley and hillside locations, or between the lee and windward side of a hill.

All of these aspects will be dealt with in turn in this report. It should be remembered that the general, regional and local elements are superimposed upon each other and thus sometimes lose their individual identity.

No technical knowledge is needed to understand this report. It is not intended to be a text in meteorology, and of necessity the physical principles involved in weather processes are discussed only in the most basic terms. The report is designed to describe in non-technical language the climate of the City of Torrance as specifically as is practical.



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CLIMATE OF SOUTHERN CALIFORNIA

The climate of Southern California can be generalized in one sentence as sunny, warm, and rather dry with the meager rain that does occur falling during the cooler months of the year. These characteristics define what is termed the "summer-dry subtropical" climate, even better known as the "Mediterranean" climate because of the great length of the Mediterranean coastline which also displays similar conditions.

Most parts of the world that are dry in summer are even drier in winter, and thus are clearly desert or semi-desert. In the case of the Mediterranean climate, wet winters intervene between the dry summers, a combination so rare that it is encountered on less than 3% of the earth's surface and only between the 30th and 45th parallels of latitude on the western borders of the land masses of which they are a part. The explanation for such scattered but patterned distribution lies in the largest elements of the planetary air and water circulation system.

Summer Circulations

Southern California is dominated during the summer months by a semi-permanent center of high pressure known as the "Pacific High" or "Pacific Anticyclone". This high pressure center is a large, storm free, pool of air formed at sea, centered about 2,000 miles off the coast at approximately the same latitude as the Los Angeles vicinity. It is roughly elliptical in shape with its eastern side tangent to and to some extent overlapping the Southern California coast, thereby creating a blocking action that effectively shunts the storms of the midlatitudes far to the north. In addition to the blocking effect, the eastern side of anticyclones is a zone of strong subsidence (air descending from higher elevations). The sinking air is warm, dry, and very stable, a condition which is not conducive to the rain-showers and thunderstorms which are associated with summer weather in midlatitude, interior areas. These two effects impose the summer drought that is a feature of Southern California weather.

The subtropical location of Southern California receives intense solar radiation during the summer and, depending upon the distance from the sea, the area ranges from hot to warm.

Winter Circulations

During the winter months the Pacific High is reduced in size and strength and follows the sun to a more southerly location. This allows the southern boundary of the midlatitude storm belt, known as the "prevailing westerlies", to work progressively southward toward the Los Angeles area. The storms of the prevailing westerlies begin to show increasing vigor with the onset of winter, and the rain from them accounts for almost all of the annual precipitation received

in this area. The rainfall amounts are not large, however, as most of the Pacific storms expend their energy farther north due to our position on the edge of the storm track.

This time of year is still relatively mild when compared to midlatitude locations. The days have more sunshine than areas farther north that get the same amount of winter rainfall. The subzero temperatures experienced in other sections of the country are not prevalent here, even in areas far from the sea.

The Temperature Inversion

One other aspect of Southern California weather that is common to the Mediterranean climate will be discussed here. As mentioned previously, the eastern side of the Pacific High is an area of strong subsidence, and as a consequence the air warms from the effects of compression as the upper air sinks into the denser, lower layers of the atmosphere. The descent stops short of the surface, however, as the subsiding air cannot penetrate the denser, underlying marine air. The exact thickness of the cool, moist marine layer is determined by the tumbling action of the wind and waves and varies accordingly. It is, however, always relatively shallow, varying from near the surface to several thousand feet over the land, depending on the relative amount of sea air that is being carried over the land surface by onshore winds. Some mixing occurs across the interface of the two air layers but, in the absence of an outside disturbance, they retain their individual identity. The temperature discontinuity between these layers is the well-known Southern California temperature inversion. That is, although the temperature decreases with altitude at a normal rate from the surface through the lower layer, it increases fairly abruptly as you move above the marine air into that overlying, as shown in Figure 1. The zone of contact of the two unlike air masses is often clearly visible to the eye, the sea air usually being hazy, the air above clear.

The strength of the inversion varies depending on the difference in temperature; the greater the difference, the stronger and, therefore, the more stable and persistent, the inversion. Variation in strength and height are influenced by pressure differences that affect the balance of the onshore-offshore movements of air along the coast. Lower pressure to the north, northeast, or east tends to lift and weaken the inversion. Any tendency of warm air aloft to subside or sink to lower elevations over the coastal area adds to the warmth of the air above the inversion, thus strengthening the inversion. Cooling aloft tends to weaken the inversion.

The inversion acts to suppress vertical air movements and thus tends to place a "lid" over the marine layer; and the stronger the inversion, the stronger the resistance to vertical movements through the inversion. Moisture is added to this lower layer of air as it passes over coastal waters and fog or coastal stratus clouds (low altitude, thin, sheet-type clouds) may form beneath the inversion. Fog or low clouds vary in height or thickness with variations in the depth of the marine layer. Haze and atmospheric pollutants tend to accumulate beneath the inversion, since dispersion through the

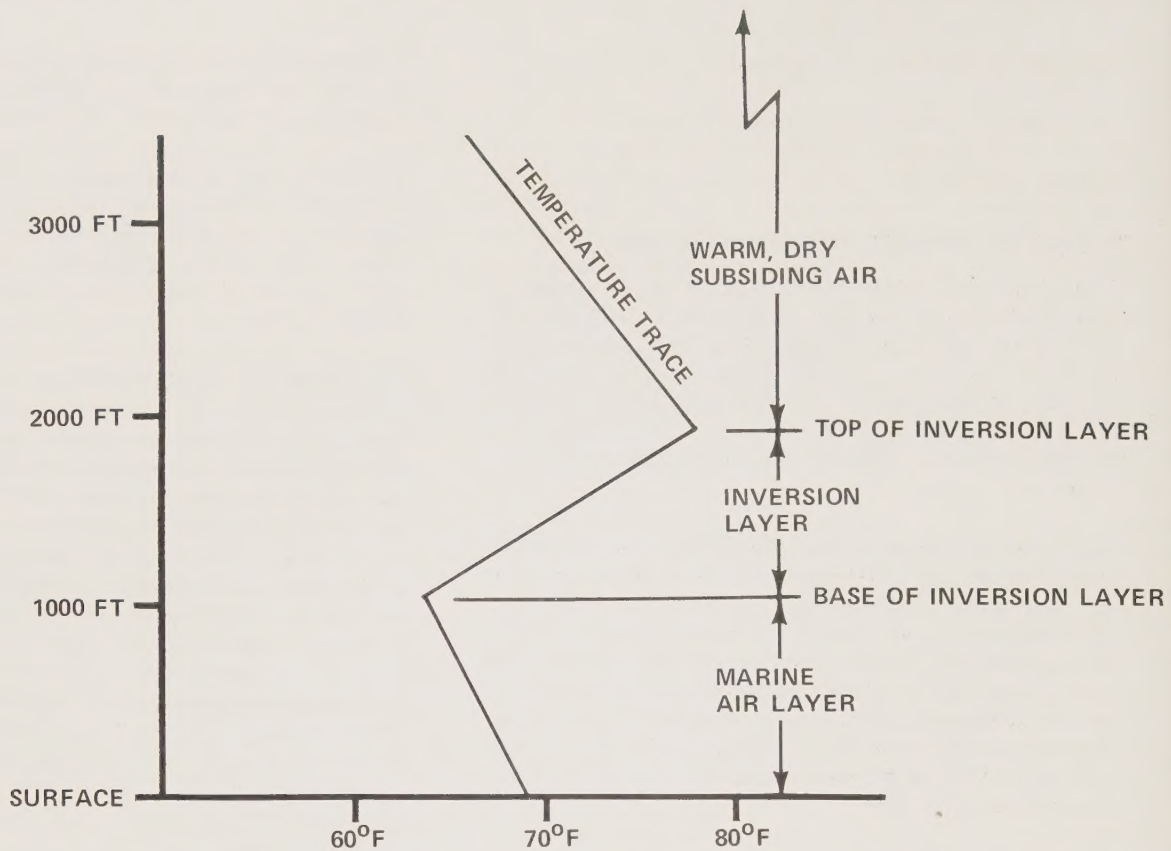


FIGURE 1: A TYPICAL SUBSIDENCE TEMPERATURE INVERSION OVER THE COASTAL AREA SHOWING THE CHARACTERISTIC TEMPERATURE CHANGE WITH ALTITUDE.

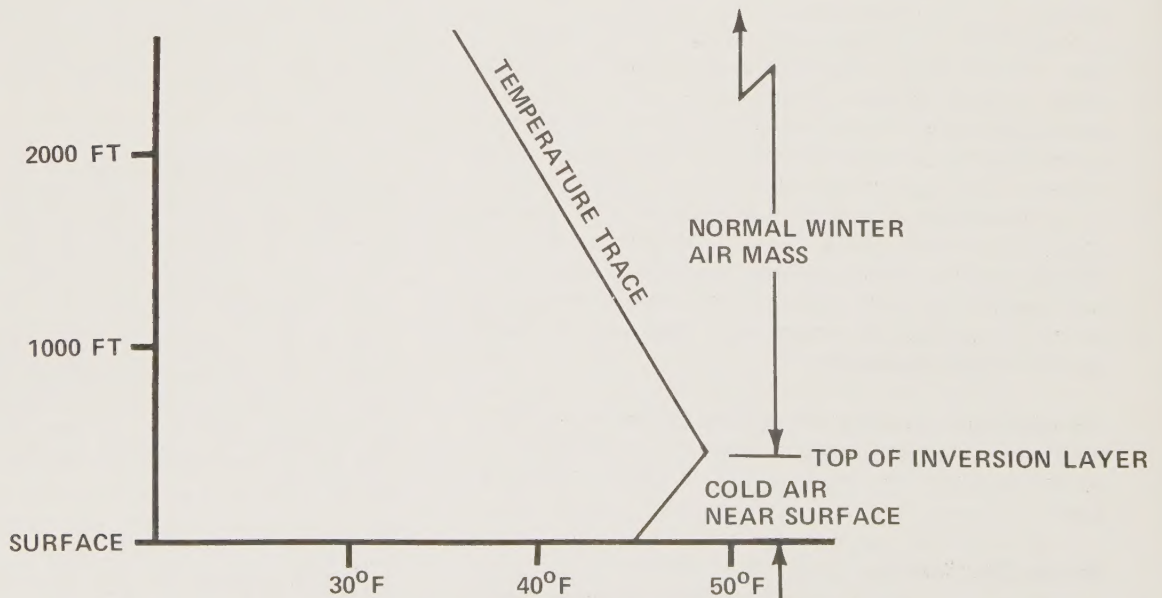


FIGURE 2: A TYPICAL WINTERTIME RADIATION TEMPERATURE INVERSION IN SOUTHERN CALIFORNIA WITH THE BASE OF THE INVERSION AT THE SURFACE.

inversion layer is strongly suppressed.

The type of temperature inversion described above is termed a "subsidence" inversion and is the type most frequently experienced in this area, particularly during the summer months. Another type of inversion occurs occasionally on cold, still, winter nights called a "radiation" inversion. The base of this inversion is on the ground and is formed by rapid cooling of the earth's surface at night (see Figure 2). It is usually quite weak in this area and disappears rapidly with morning heating. The radiation inversion, when it forms, can suppress vertical mixing of the atmosphere for a few hours, but its effects are seldom experienced past mid-morning.

THE COASTAL CLIMATE

The Coastal Plain

The City of Torrance is located on the Los Angeles coastal plain, a broad, flat expanse of land open to the sea. The Pacific Ocean exerts a moderating influence on the climate of the area, and the mountains and foothills that mark the inland boundaries of the coastal plain act as a buffer against the extremes of summer heat and winter cold that occur in the interior. Prounounced differences in temperature, humidity, cloudiness, fog, sunshine and rain occur over fairly short distances on the coastal plain and the adjoining foothills due to local topography and the decreased marine effect further inland. In general, temperature ranges are least and humidity highest close to the coast, while precipitation increases with elevation in the foothills.

The Maritime Fringe

The area predominately under the influence of sea air is referred to as the "maritime fringe". This zone extends inland from the coastline at varying widths because geographic barriers tend to block the shallow marine air layer as it traverses the land surface (see Figure 3). Over the Los Angeles coastal plain the sea air flows with relative ease and so all of Torrance is well within the maritime zone.

Only in the maritime fringe do we find stations with records of summers cool enough and winters warm enough to satisfy the stipulation that the warmest month be below 72°F and the coldest month above 50°F. The mean daily temperature in Torrance, for instance, ranges between 53°F in January to 68°F in July and August.

The "California Current", a relatively cool ocean current off the California coast, is primarily responsible for the exceptionally mild summers of the maritime fringe. In fact, the climate of coastal Southern California is actually a minor variant of the Mediterranean climate known as the "cool-summer" subtype. One condition necessary for occurrence of this subtype is the cool ocean current mentioned above; the other is prevailing onshore winds.

Prevailing Onshore Winds

The mildness of the maritime fringe is, as alluded to above, the result of the movement of sea air over the land surface.

The air flow across the coastal strip from the sea is maintained during the summer by the characteristic presence of a high pressure area off the California coast (Pacific High) and a low pressure area over the southwestern interior (Southern California and Nevada deserts). The desert low pressure area is heat-formed (known as a thermal-low) and is a very persistent summertime feature. Since air movement tends from high to low pressure, this accounts for the persistent onshore flow. Superimposed on this flow is the land and sea breeze cycle which increases the onshore wind during the day and decreases it slightly at night. The land and sea breeze cycle will be discussed later.

In the cooler months, when the Pacific High is reduced in size and strength and high pressure is often present inland, the onshore flow resulting from this pressure difference is very weak and erratic. However, a general onshore drift is still present because the Southern California coast is now influenced by the planetary circulation of the prevailing westerlies. In addition, storms moving through the area at this time of year can bring strong onshore winds.

Temperature Modification By The Ocean

On a winter day in the Southern California area, when the sun is low in the sky even at midday, the amount of heat received from sunrise to sundown is only half that received during a summer day. This kind of difference, of course, is the reason for the seasons in the midlatitudes. Oceans as well as land surfaces receive greater amounts of solar radiation (termed insolation) in the summer than the winter and are, therefore, correspondingly warmer in the summer. However, the much higher heat storage capacity (specific heat) of water as opposed to land means that the oceans do not heat up or cool down as much or as fast as land receiving the same amount of insolation. As a result, the ocean temperature remains relatively constant and acts to buffer the temperature extremes that would otherwise be expected over the adjacent land surface.

This buffering takes place in the summer as warm air moving over the relatively cool sea surface is cooled by contact with and by absorbing water vapor from the ocean. This cooled sea air is then carried over the coast by the onshore air flow during the day. In addition, the low clouds which frequently form in the marine air layer along the coast reflect much of the incoming sunlight. The result of these effects is summer high temperatures far lower along the coast than in inland locations where the effects of the sea air are greatly reduced. The relation between summer afternoon temperatures (actually, the mean maximum temperatures in July) in Southern California and distance from the sea is shown in Figure 4. For the sake of objectivity, the distance from the sea represents the shortest line connecting a given station with the coastline, even though the movements of sea air seldom follow a straight line path over land. Since the trend line shown in Figure 4 approximates a line of best fit, the stations on the warm side of the trend line can be thought of as places with less than average access to sea air, while the opposite should be true of stations cooler than the trend line. Beyond the mountain barriers that surround the Los Angeles coastal plain, distance from the sea is probably less important than altitude as a control

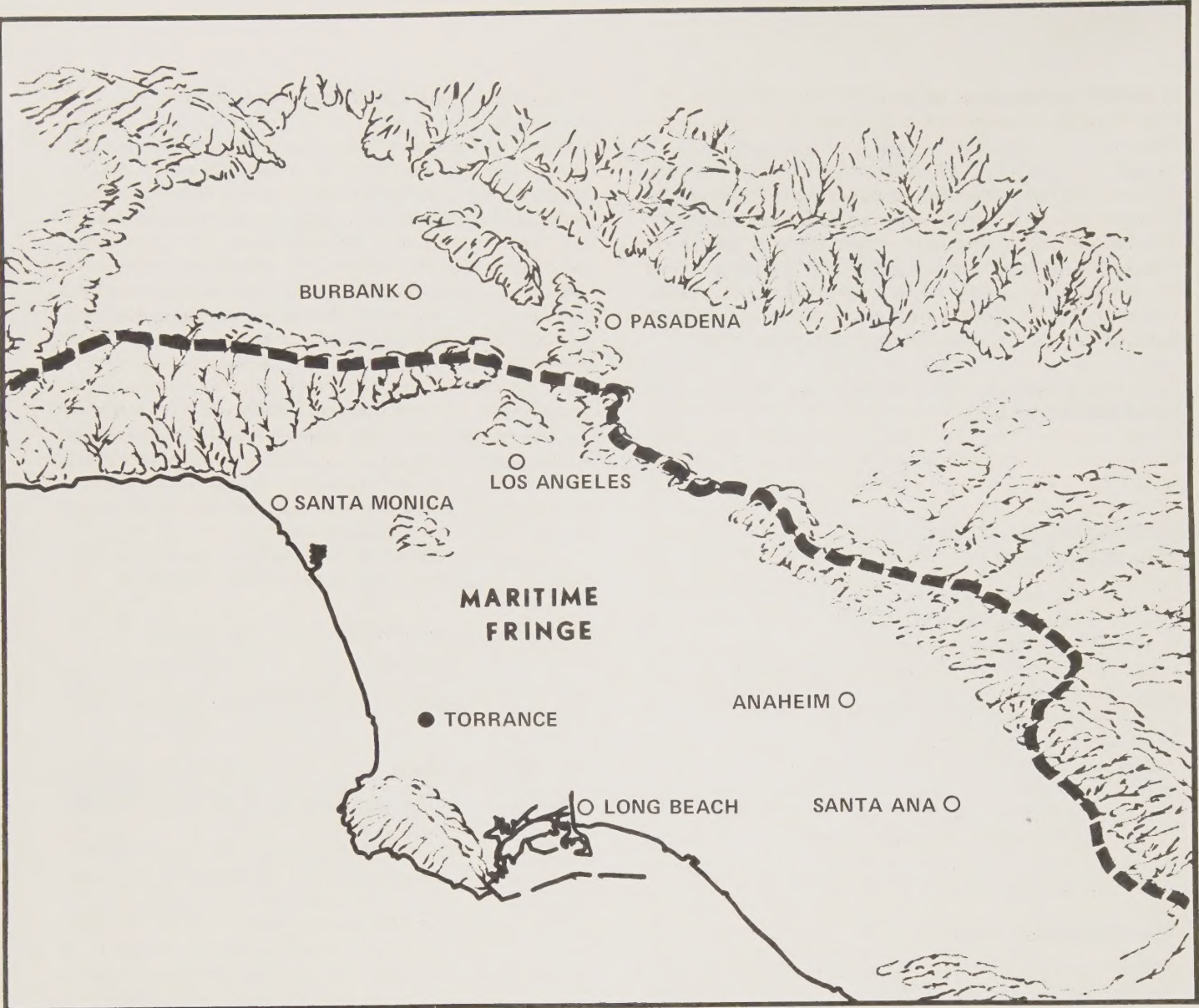


FIGURE 3: THE LOS ANGELES COASTAL PLANE. THE APPROXIMATE INLAND BOUNDARY OF THE MARITIME FRINGE IS INDICATED BY THE DASHED LINE.

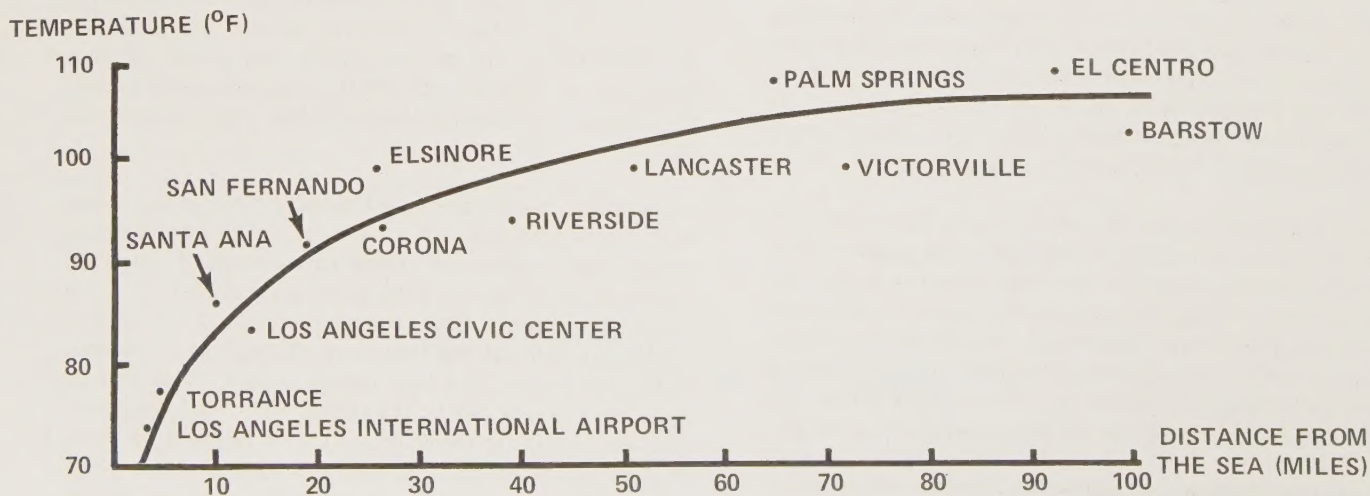


FIGURE 4: SUMMER AFTERNOON TEMPERATURES AT SELECTED LOCATIONS IN RELATION TO DISTANCE FROM SEA MEASURED.

of summer temperature. Beyond 100 miles inland the marine influence is negligible and the graph terminates at this point.

In the winter the onshore flow is not as regular or usually as strong as during the summer, and the difference between the daylight ocean and land temperatures is greatly reduced. The result is that the maximum temperature over the coastal strip is only slightly modified by the marine influence and the coastal high temperatures approximate those farther inland (at the same altitude, of course).

The accumulation of moist marine air near the coast does have a significant effect on the nighttime minimum temperatures, however. The water vapor in the sea air effectively holds much of the day's heat near the ground in the coastal sector. Torrance, for instance, averages only 3½ days a year below freezing and in January the mean daily minimum is 41°F, a significant difference from localities only a few more miles inland. In fact, the marine air in winter, unlike summer, normally has a significant influence only in the immediate coastal area.

Therefore, due to the buffering process of the adjacent ocean waters, the coastal temperatures show much less variation, both seasonal and diurnal, than interior locations at the same latitude.

SMALL SCALE CIRCULATIONS

Under special circumstances certain wind circulation patterns develop which are essentially small scale as compared with the large movements of the air associated with the general circulation pattern. These small scale circulations in the atmosphere arise from local heat differences. The land and sea breeze cycle and the "drainage" wind are local circulations which meet these criteria.

The Land Breeze/Sea Breeze Cycle

The sea breeze is created when the land warms more than the adjacent ocean surface by day, mainly during the summer months. The warm air over the land expands, becoming less dense than the over-lying air and thus rises. The air over the water remains relatively dense, and, therefore, does not rise, but sweeps across the shoreline to fill the void left by the ascending air over the land surface. This onshore flow in the lower levels of the atmosphere is the sea breeze.

During the summer the sea breeze usually begins between 10 a.m. and 11 a.m. offshore and gradually works inland, reaching its peak in midafternoon and subsiding as the land cools in the evening. The sea breeze is practically a daily occurrence in the warm months of the year as there are no storms or other disturbances associated with the general circulation pattern to disrupt its influence in this area. The sea breeze far overshadows the previously mentioned general onshore flow from the Pacific High. During the cool months, the necessary temperature difference occurs infrequently and the sea breeze has its least influence. It is rare, shallow and weak at this time of year and loses its identity

to the more dominant winter circulation patterns.

The land breeze occurs when the conditions are reversed, i.e., the warmer ascending air is over the water and the colder, denser air is over the land surface. These conditions would be expected at night as the ocean temperature stays relatively constant and the land cools fairly rapidly. In actuality, during the summer the temperature difference between land and water at night is slight, and the resultant land breeze is very weak. During winter nights, the land breeze is better defined but still quite shallow, resulting in an offshore drift in the lowest levels of the air mass near the coast. In addition, the land breeze, like the sea breeze, is a clear weather phenomenon and is destroyed by elements of the general circulation that frequent this area in the winter. So the maximum land breeze could be expected on a clear, still, winter night. This is exactly the same condition that the lowest temperatures can be expected, and here is where the land breeze has its influence on the coastal climate. The lower layer of cold air is continually carried out over the water to be replaced by air descending from above. The descending air is warmed slightly by compression thus moderating the low temperature by constantly removing the coldest layer of air.

The land and sea breeze cycle is pictorially represented in Figures 5 and 6.

The Drainage Wind

The same conditions that give rise to the maximum land breeze, i.e., clear, still, cold nights, also set the drainage wind into operation. This microscale feature occurs when the air layer just above the ground becomes cold (and therefore dense) due to contact with the cold, winter ground. The cold, dense air flows down the slopes of the land close to the ground. On the air-drained slopes the drainage wind has the same effect as the land breeze; removing the lower layer of cold air. In low spots (drainage basins), however, the drainage wind has the opposite effect by collecting the cold air flowing down the surrounding slopes (see Figure 7). Both conditions exist in Torrance with the air-drained slopes roughly corresponding to the El Segundo Sand Hills in the western portion of the City and the Torrance Plain being a drainage basin area in the east portion. Due to the previously mentioned moderating factors, the minimum temperatures do not get excessively cold in the drainage basin area of Torrance, but when conditions are favorable, the drainage basin area is slightly colder than the sand hills section.

In summary, the sea breeze, or onshore flow, is at a maximum on summer days. It is very regular and quite strong during these months and tends to moderate the summer maximum temperatures for a good ways inland. The land breeze, or offshore flow, occurs primarily during winter nights, but without the frequency, strength or persistence of the sea breeze. The land breeze is most developed on clear, calm winter nights; the nights when the lowest temperatures would be expected, and has a moderating effect on these temperatures. The drainage wind occurs only on calm, cold nights and has a moderating effect on the air-drained slopes of western Torrance, but intensifies the

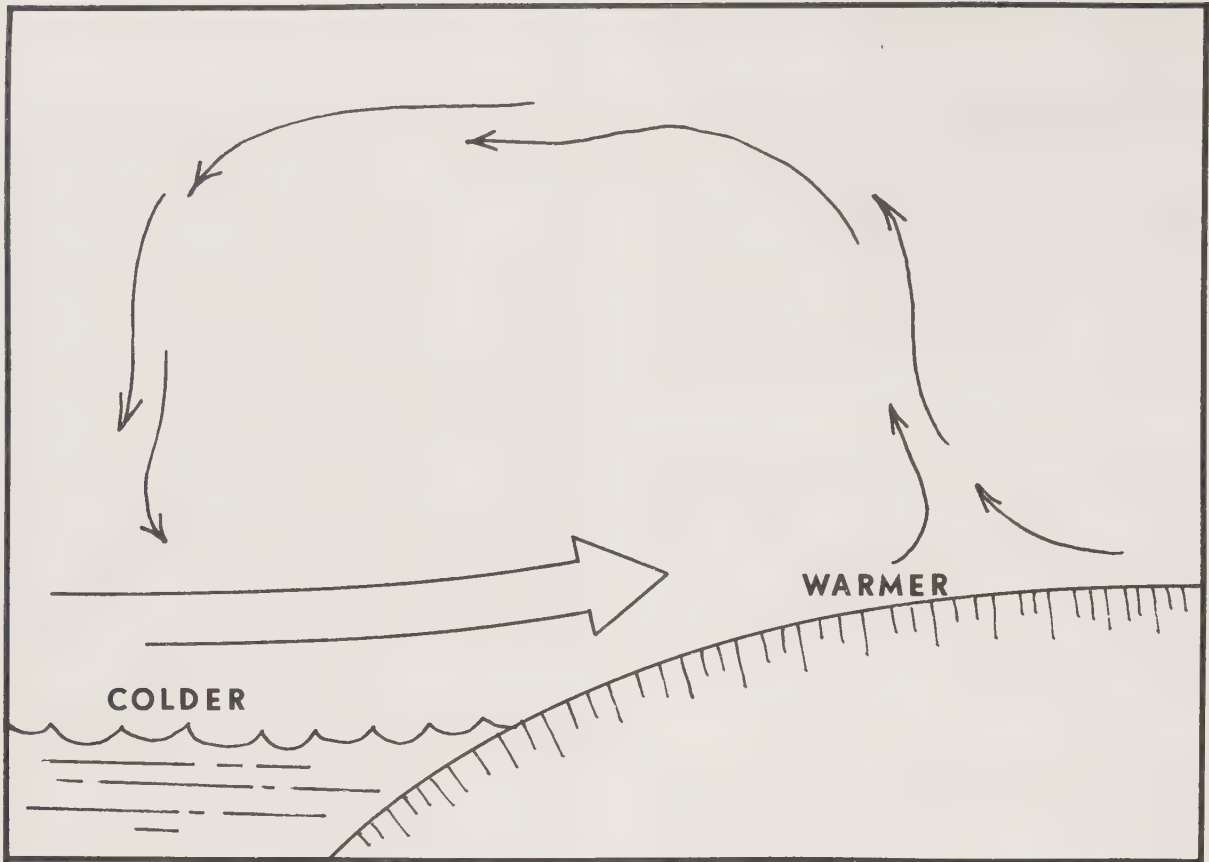


FIGURE 5: TYPICAL SEA BREEZE AIR CIRCULATION PATTERN

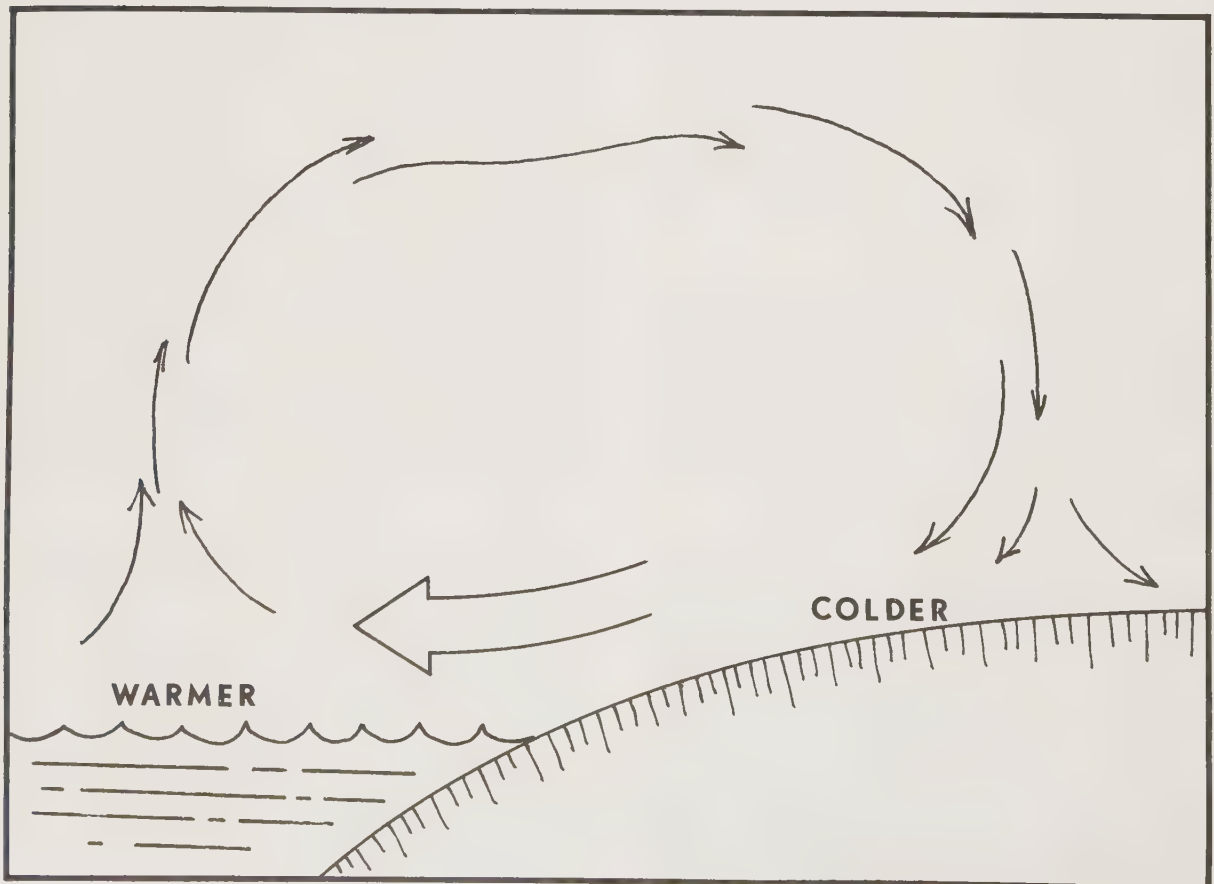


FIGURE 6: TYPICAL LAND BREEZE AIR CIRCULATION PATTERN

nighttime cooling in the drainage basin of eastern Torrance. In both cases the effect is slight, but a measurable difference in minimum temperature will exist between the two areas of the City when conditions are favorable.

The Catalina Eddy

The Catalina Eddy, though not a small scale circulation, is a small scale modification of the general flow and so will be included here.

The difference in pressure between the ocean high pressure and the characteristic low pressure inland during the summer maintains a northwest flow of air along the California coast during the summer months. Where coastal hills come close to the ocean the northwest wind is "squeezed" as is water in a narrow stream bed, and we often find very strong jets of air flowing past these barriers that reach out from the Coast Range. The air flow is further strengthened by the temperature inversion which keeps a low level "lid" on the jet area that does not allow any of the wind speed to be dissipated by vertical movement.

Downwind from these jets we find atmospheric whirlpools (eddies), again like water in a stream. South of each jet the air stream swings in a wide arc toward the land causing belts of strong onshore flow of marine air. One of the most pronounced jets is near Point Arguello, west of Santa Barbara, where the coast makes a sharp bend toward the east. During the summer, Point Arguello will often experience winds of 25 to 35 knots. The wind jet extends far to the south in diminishing force and produces the largest of the eddies embracing the area from Point Arguello to San Diego, known as the Catalina Eddy (see Figure 8).

The Catalina Eddy will form when northwest winds are fairly strong over the coastal waters. During this time, the air flow could be expected to arrive over Torrance from an inland direction thereby minimizing the marine influence over the area. However, due to the eddy effect, winds are actually more southerly than normal; the more well developed the eddy, the greater the southerly component. The actual wind direction over Torrance may not show this trend exactly because of the deflecting influence of the Palos Verdes Hills, but the air over the City will have arrived from a southerly, over water direction.

During a strong eddy, the swirling sea air exerts a strong upward push on the temperature inversion "lid" and the marine air layer can deepen to as much as 6,000 feet. The increase in depth of this moist air, coupled with the onshore flow produced during an eddy, produces the extensive overcast days of late spring and early summer. Due to the depth of the marine layer and the strong push of coast air inland, visibility is usually increased, and significant cooling often takes place as the stagnant air mass, which usually proceeds a strong eddy, is moved out of the area.

FOG AND LOW CLOUDS

It is a characteristic of air that the warmer it is the more

water vapor it is able to "hold" before condensation occurs. When the air contains all of the water vapor it can hold relative to its temperature, it is said to be "saturated". The relative humidity of saturated air is 100%. It is apparent, therefore, that a parcel of air with a given amount of water vapor can be cooled to a point where saturation would occur without the addition of any more water vapor. If air is cooled to a temperature below its saturation point, the excess water vapor condenses to form fog or clouds, depending on the level where condensation takes place. The coastal fog and low clouds prevalent during the spring and summer in this area are formed by just such a process.

As mentioned earlier, during the warm months of the year there exists a general onshore flow of air from the ocean associated with the ocean high pressure and the heat induced low pressure of the interior. This sea air is relatively warm and contains a large quantity of water vapor. As the warm, moist air moves toward the coast, it crosses a cold band of water off shore known as the "California Current". Contact with this cold water cools the sea air below its saturation point and fog and/or low clouds are formed off shore to be swept across the coast by the onshore flow.

The coastal fog and low clouds (stratus) are in reality the same weather element, and most of our fog is merely a cloud whose base extends to the ground. Fog usually forms as air moves across the California Current landward. Due to the mixing in the marine layer, the fog will tend to rise, forming a stratus deck, a relatively shallow, sheet type cloud that forms entirely in the marine layer with the top of the cloud deck at the base of the inversion. As a result of this characteristic, the height of the temperature inversion is the principle determinate of whether the sea breeze will bring fog or stratus; low inversions lower the cloud base and bring fog and high inversions result in stratus.

The summer fog and stratus usually begin forming over the coastal region during the night and gradually clear with midday warming. They begin to reform up near the base of the inversion when evening or nighttime cooling sets in. Thus we can see the reason for the almost daily occurrence of fog and low clouds along the coast during the summer.

Occasionally, fog rolls across the coastline at other times of the day or year. Sometimes fog will persist over the offshore waters till late in the day and then be swept onshore by the afternoon sea breeze. Usually, this is of short duration as the fog or stratus itself cuts off the warming over land that causes the sea breeze that brought it onshore. During the late fall and winter, fog is less frequent than the warmer months, but dense fog is more likely to occur. These "pea-soupers" are associated with weather "fronts" or with rare strong inversions which are also very low at this time of year, and the typical cold, winter land surface which does not lift or dissipate the fog as a warm land surface will do. This characteristic is illustrated in Table 1 where stratus and light fog (ceiling less than 1,500 feet and/or visibility less than 3 miles) is more prominent in the summer, but heavy fog (visibility less than ½ mile) is at its maximum during the winter months at Torrance Airport.

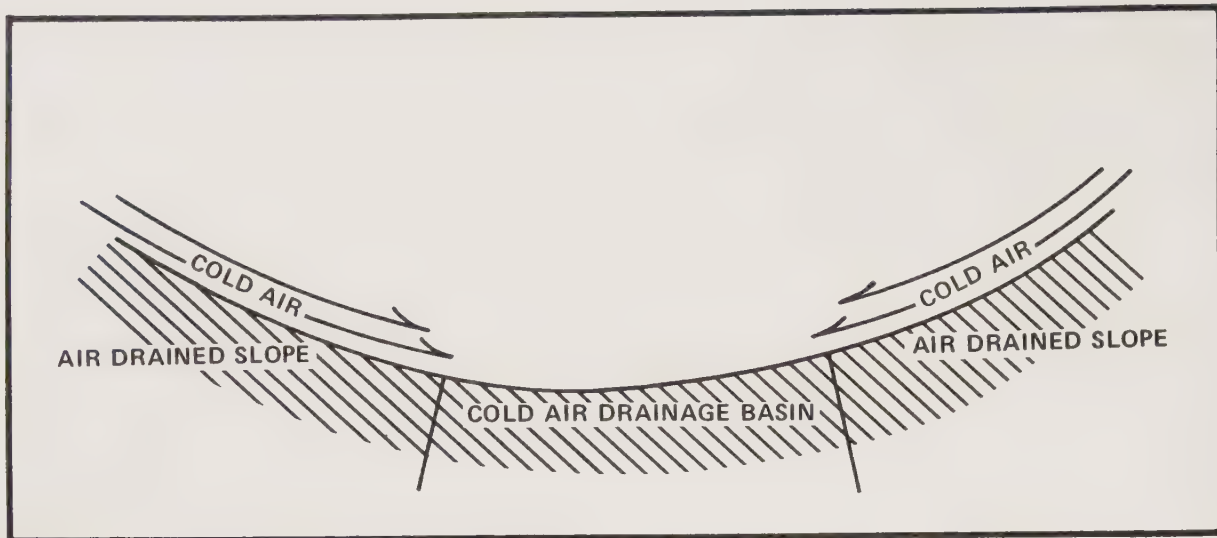


FIGURE 7: ON A STILL, WINTER NIGHT THE AIR LAYER JUST ABOVE THE GROUND COOLS RAPIDLY, BECOMES MORE DENSE, AND TENDS TO "SINK". IN THIS MANNER THE COLD AIR IS REMOVED FROM THE SLOPES AND COLLECTS IN LOW SPOTS. THE RESULT IS THAT SLOPES REMAIN WARMER THAN ADJACENT BASINS.

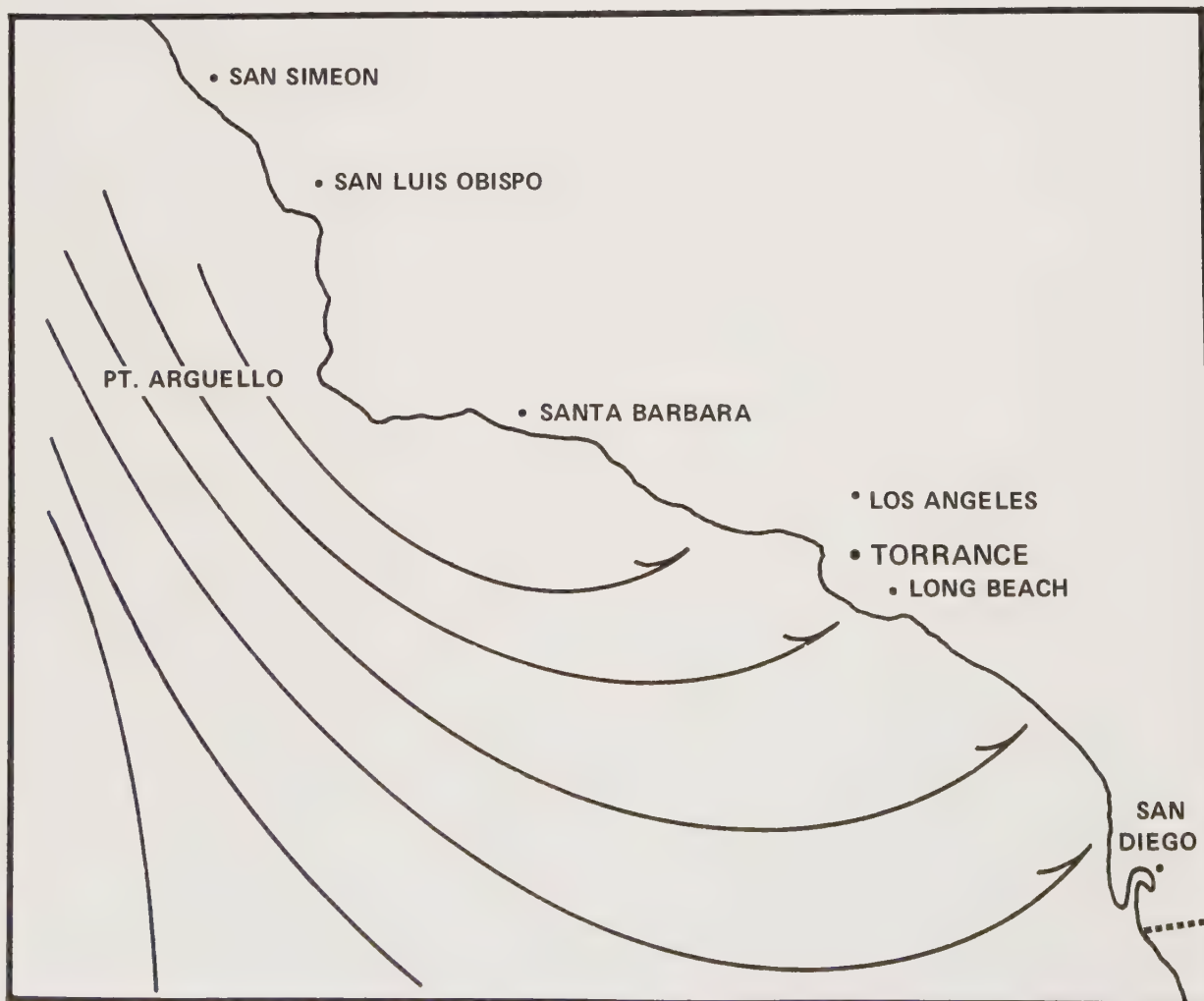


FIGURE 8: A STRONG NORTHWEST WIND OFF THE COAST AS MODIFIED BY THE CATALINA EDDY EFFECT

STORM TYPES AND ASSOCIATED WEATHER

As winter approaches and the Pacific High retreats southward, storms approach the Southern California area with increasing frequency. The nearness of the storm center usually determines the amount of rain and wind to reach our area. Occasionally, a "secondary" storm center will develop much closer than the main center and cause unexpected amounts of rain and wind. The following is a brief description of storm types that usually effect our area and the "typical" weather sequence associated with them.

The Northwest Storm

The type of storm most common to Southern California comes from the northwest, moves swiftly across the Southland and continues eastward into Arizona. If the storm (low pressure) center is close, it brings strong shifting winds and a brief period of showers that seldom continue as long as 24 hours. As the storm approaches the coast, raw, gusty winds from the southwest and increasing cloudiness proceed light rain. The rainfall and winds increase to a maximum as the storm front arrives. The rain slackens and the winds shift to the west or northwest with the passage of the storm and skies begin to clear. This is a blustery type of storm, but is seldom a flood-rain threat because the moisture content is usually not too high (due to the storm's passage over the cold northern Pacific waters) and the duration of rainfall is usually short.

As the storm recedes eastward over the Rockies, the winds die down, nights become clear and cold with our lowest temperatures on the coast being experienced during this time. Visibility in the Los Angeles Basin has been better than average during the sequence of changes, since the temperature inversion is raised and weakened by the approach of the storm and is destroyed entirely as cold air following the storm arrives over the area.

Santa Ana Winds

The most common sequence of events following the passage of a winter storm from the northwest is for the direction of the wind to proceed clockwise around the compass. A change from northwest to north or northeast winds brings continental rather than maritime air to the coast attended by falling humidity and the disappearance of clouds. These strong dry winds from the interior are the famed Santa Ana, or Santana Winds.

Conditions favorable to Santa Ana winds occur after a weather front has moved inland through Northern California and Nevada followed by a high pressure area that has pushed in behind the front. This high pressure air mass begins to slow down over land and is left stranded for a day or two over the Great Basin where it becomes colder and, therefore, more dense (higher pressure) over the relatively cold land surface. Just formed, the mound of cold air dissipates by flowing just above the surface toward the lower pressure along the Southern California coast. As the air descends to the coast, it is warmed by compression, and the rising temperature of the descending air lowers the relative humidity. If, after its descent to the coast, the air is colder than the air overlying the coastal plain, it will push the coastal marine air out to sea. If the air descending from the

mountains has warmed enough to reach the coastal plain at a higher temperature than the marine air, it will tend to ride over the marine air, and its effects will be localized to the canyon areas. Meteorologists try to consider these temperature contrasts in making a distinction between the "cold type" Santa Ana which is more general and destructive, and the "warm type" which is quite localized and usually less intense. In any case, the coastal area from Santa Monica to Long Beach is well protected from the strong winds, and they never approach the velocities experienced elsewhere.

The favored season for Santa Anas is from November through January, although conditions similar to the Santa Ana may occur at other times of the year with dry northeast winds of lesser intensity, bringing abnormally warm temperatures along the coast. Usage of the Santa Ana label has become less precise, and is often used to identify these more general northeast wind conditions.

The temperature of the Santa Ana Winds will vary over a wide range, but as the temperatures are keyed to altitude during these episodes the coastal areas, being the lowest, are also usually hotter than even the high deserts for a couple of days. Occasionally, a very hot Santa Ana condition will develop during the fall or spring and the Southern California coast will be the hottest spot in the country.

The South Or Southwest Storm

Less common than the northwest storm but of real concern is the type of storm that comes to us from the south or southwest. Because of its passage over warmer water, this storm type arrives with warm, very moist air pulled up from the tropical regions, and produces some of the heaviest rain in Southern California. These rains may continue for 36 to 48 hours and the potential for flooding is obvious.

Before the rain begins, extensive cloudiness and relatively light southeast winds occur over the coast. With the onset of precipitation, winds shift gradually to the southwest or west but remain relatively light. Rain and cloudiness slowly decrease as the storm moves inland. Cold air remains to the north, however, and the marked visibility increase and crispiness of the northwest storm passage is not apparent here.

The Westerly Storm

Another uncommon type is the westerly storm which moves eastward at midlatitudes toward the California coast. The moderate amount of moist air pulled in by this storm is still enough to qualify this as a steady rain type like the southwest storm rather than the showery northwest type. Frequently, the westerly storm develops into a series of storm centers which approach the coast along the same path, one after the other. When this happens a series of recurring rains may continue for a week or more with changeable winds and partial clearing between storms. The cold air remains to the north with moderate temperatures over our area until the last storm of the series passes. The last storm brings with it the cold air, along with the strongest wind and the heaviest rainfall of the episode.

If the storm centers cross the coast far enough to the south

(San Francisco—Monterey area), all areas of the Los Angeles coastal plain are subject to flooding. Much lighter rain can be expected in this area if the storms track further north, while northern California and the Pacific Northwest are deluged.

Violent Storms

The most violent weather, thunderstorms, hurricanes and tornadoes are usual summertime features in many areas of the country, whereas coastal Southern California is almost completely free of any weather at all this time of year.

Thunderstorms are rare along the coast and never approach the intensity of other areas. Torrance averages only two days a year with thunderstorms.

Tornadoes of the Great Plains variety really never occur over the coastal strip. Although it is not impossible, the best we have done over the land is a well developed dust devil. Water spouts, which are basically tornadoes over water, occasionally do develop to moderate intensity but seldom come aground.

Hurricanes, as they track out to sea far to the south, can send humid tropical air and an occasional thunderstorm over our area, but in recorded history have never run aground in our area with hurricane force winds. A few dying hurricanes have gone inland near San Diego; the last one in September 1939 brought damaging wind to the coastal area and record rainfalls throughout the coastal plain (5.51 inches at Torrance).

The violent summer storms feared in many parts of the country, therefore, are of little concern here.

SMOG

The word smog probably came out of England to describe the mixture of fog and coal smoke that has long been encountered there. In Southern California the word is primarily applied to the oxidation type of air pollution that plagues the area.

Although many areas are troubled with air pollution, the Los Angeles Basin has a natural combination that intensifies the problem. With the winds blowing predominately onshore on one side, surrounded by mountains and foothills on the other sides, and our frequent temperature inversions placing a lid over the coastal plain, the pollutants do not disperse readily into the atmosphere. Even our abundant sunlight seems to be working against us by reacting with combinations of emissions to produce more toxic, eye-irritating chemical combinations (photochemical or oxidation smog). The meteorological factors affecting air quality in the Basin are, therefore, the amount of sunlight received, the onshore component of the wind and the strength and height of the temperature inversion. These factors are, of course, related to seasonal changes.

Photochemical Smog

The air pollution problem in the Los Angeles Basin is usu-

ally defined in terms of photochemical smog concentrations, this being the most salient form of air contamination for most of the area. Unlike most air pollution problems which are caused by the unpleasant effects of accumulations of contaminants as emitted, photochemical smog is created in the atmosphere as the result of sunlight energized reactions among specific emitted contaminants. The presence of reactive contaminants, however, is not the sole requisite to the occurrence of photochemical smog. In addition, certain meteorological conditions must be met. The nature of photochemical smog is such that several hours of exposure to sunlight are required for completion of the reactions which produce the undesirable effects. Therefore, limited atmospheric dispersion resulting from relatively light winds and a strong temperature inversion (subsidence inversion) in addition to sufficient sunlight, is needed to initiate and sustain the photochemical reaction. These conditions are common in the Los Angeles area from July to November, and this is correspondingly the period of most persistent photochemical smog. These conditions can occur during other seasons, but do so infrequently.

The southwest coastal area where Torrance is located lives up to its advanced billing as having superior air quality to the Basin as a whole in terms of photochemical smog (photochemical smog is best represented by ozone concentrations). The basic reason for the relatively low ozone concentration along the coast is the time lag involved in the photochemical reaction. During the summer and early fall, when the photochemical smog is most prevalent, the sea breeze arrives at about the same time as the start of maximum ozone formation. Thus the reacting contaminants are carried inland before the formation of photochemical smog is completed, and the coastal zone normally remains relatively free of high ozone concentrations. During the winter and spring the temperature inversion is neither strong nor persistent, and the photochemical reaction rarely has sufficient time to reach the high concentrations of summer.

A significant variation in the air quality of the near coastal sector occurs when a strong temperature inversion occurs with no wind or wind from the eastern sector. During these episodes photochemical smog tends to accumulate over the coastal area. Fortunately for Torrance and the other coastal cities, the combination of easterly wind and strong temperature inversion is a rather infrequent occurrence.

Primary Contaminants

Although photochemical smog is the type most commonly associated with the Los Angeles area, it is not the only air pollution problem. There is also a general air pollution problem caused by the accumulation of emitted primary contaminants which normally do not react photochemically. Unlike photochemical pollution, meteorological conditions, coupled with high source emissions, result in relatively high concentrations of primary contaminants in the southwest coastal area. High concentrations of the primary contaminants usually occur during the early morning or nighttime hours because they are associated with low inversions and weak winds. As soon as heating occurs, the inversion begins to lift, and the contaminant concentrations begin to decrease due to the larger air volume. For this reason, and because they do not react photochemically,

their highest concentrations and most intense effects are measured close to their source areas. Concentrations rise, peak, and later decline as the inversion base is raised by surface heating and wind speed increases. During the day, although concentrations are lower, the relative distribution pattern remains unchanged with emissions seemingly in equilibrium with diffusion downwind. Nighttime and early morning inversions are lowest and most frequent during the winter (radiation inversions) so the general air pollution problem is most commonly associated with that season.

Sunlight and Fog

During summer mornings when the inversion is lowest, vehicular emissions are the highest, and the sea breeze has not begun to carry the pollutants inland, the sunlight needed for the creation of photochemical smog is usually blocked out by our morning fog and low clouds. As the fog and low clouds are dissipated by the increasing heat of the day, the inversion rises, and the sea breeze arrives to carry the pollutants inland before the photochemical reactions take place. Thus a beneficial effect results from the summertime coastal cloudiness, at least in terms of photochemical smog. Other constituents of air pollution are not related to the amount of sunlight received and do not benefit from overcast or foggy mornings. In fact, one pollutant, sulfur dioxide, is actually adversely affected from an air quality standpoint when mixed with fog. The water droplets which constitute fog react with sulfur in the air to form toxic sulfur acids. Since the industries primarily responsible for sulfur dioxide emissions are concentrated in the south-central portion of Los Angeles County, concentration of this contaminant can be expected to be higher in this area than the Basin average.¹ In addition, when fog is present along the coast, the inversion layer is usually very low and onshore winds are weak which causes emission buildup near the source. Therefore, fog is usually accompanied by above average sulfur dioxide concentrations, and the importance of this contaminant to south coastal air quality should not be underestimated.

MICROCLIMATOLOGY OF TORRANCE

As mentioned earlier in this report, the City of Torrance lies completely within the area of maximum oceanic influence of the Mediterranean climate known as the maritime fringe. Even within this smaller division, however, localized differences exist and, for the purposes of this study, these differences will be called the microclimatology. The microclimate of Torrance is a product of local geography. In Torrance three geographic features affect the microclimate of the area. South of the City lies the Palos Verdes Hills which jut out into the Pacific from the coast. The other features are the Torrance Plain, an air drainage basin located in the eastern section of the City and the El Segundo Sand Hills in the west.

The Effect Of The Palos Verdes Hills On The Prevailing Cloud Cover Of Torrance

During the summer months the onshore flow is predominately from a west-southwest direction. The Palos Verdes Hills rise rapidly from the shoreline and deflect the wind before it crosses the southern portion of the City. This alters the wind direction and speed somewhat along the southern portion of Torrance, but the affect on the cloud cover is slight. Occasionally, however, the cloud cover will tend to be deflected around the sides of the Palos Verdes Hills and leave a "hole" in the cloud deck on the lee side of the Hills. In this case parts of Torrance or all of Torrance and parts of the surrounding area will be the only area in the vicinity that is not overcast. For this condition to occur many meteorological conditions must be met, but of primary importance is the modification of the onshore winds by the Palos Verdes Hills.

Local Geographic Influences On The Maximum and Minimum Temperature In Torrance

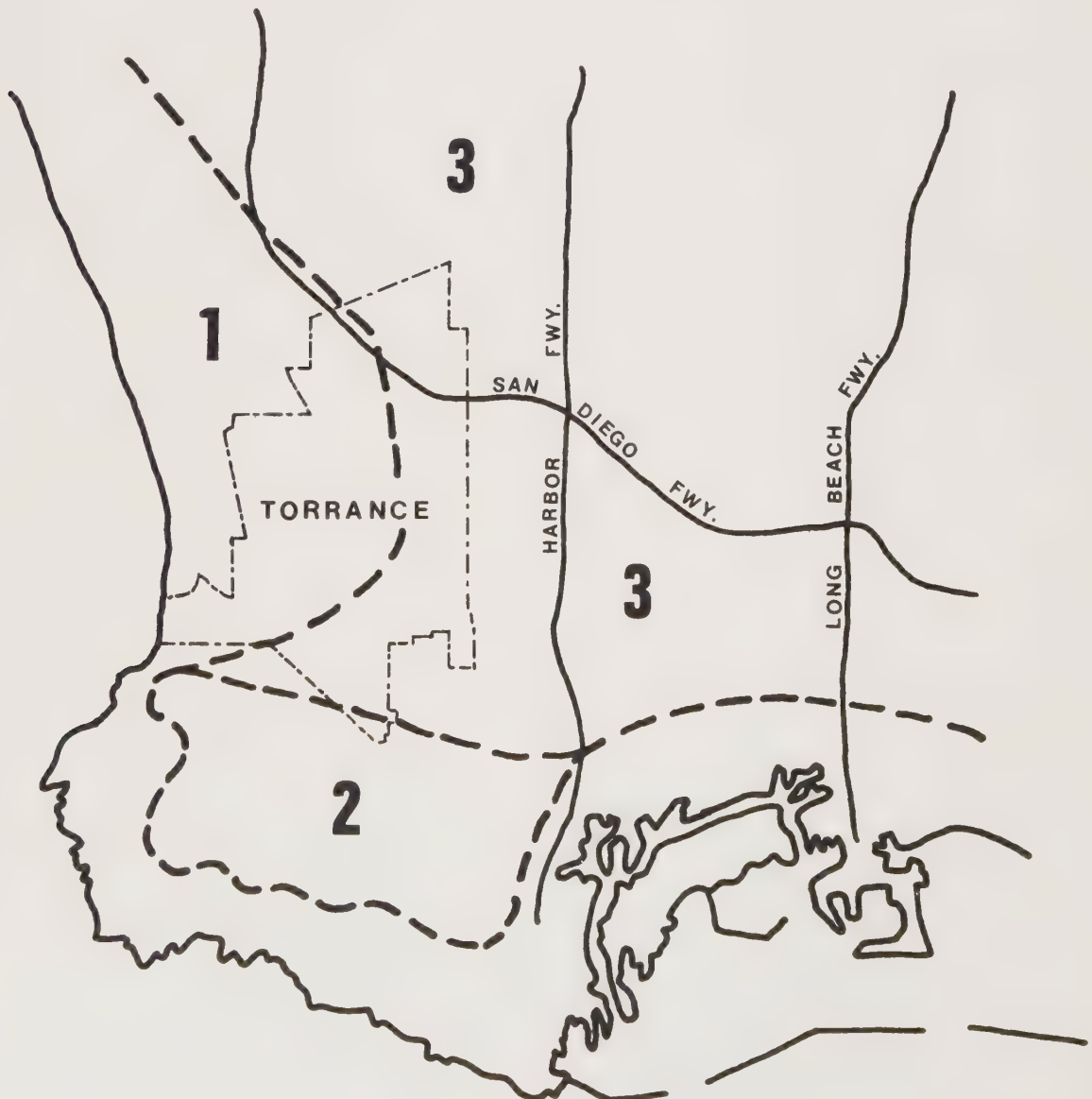
Since only one observation station exists in the City at Torrance Municipal Airport, exact temperature differences within the City are not known. However, by using data from the observation stations at Los Angeles International Airport and Torrance Municipal Airport reasonably, accurate conclusions can be made. Both stations are approximately the same distance from the ocean. The Torrance Airport is near the southern border of Torrance and is under the maximum influence of the Palos Verdes Hills whereas Los Angeles International Airport is not affected by any small scale geographic barriers. The deflections pattern of the Hills decreases somewhat the affect of the onshore flow over the coastal plain. Since these onshore winds are primarily responsible for moderating the maximum temperatures over the coastal area, we would expect the daily high temperatures to be somewhat higher at Torrance Airport than at Los Angeles International Airport. This is the case as the maximum temperatures average one to three degrees higher at Torrance throughout the year. The Torrance Airport is representative of the southern section of Torrance as all of this area is affected by the Palos Verdes Hills. However, the northern section of the City, due to its distance from the Hills, would be better represented by maximum temperatures at Los Angeles International Airport.

The location of Torrance Airport at the foot of the Palos Verdes Hills also has an affect on the minimum temperatures observed at this station. The deflection of onshore winds during the summer nighttime hours by the Hills allows the temperature to drop lower than if this influence did not exist. During the winter months when onshore flow is weak, the drainage wind becomes significant. The location of Torrance Airport in the drainage basin area as opposed to Los Angeles International located on air-drained slopes also helps account for the lower minimum temperatures experienced at Torrance Airport. The combined effects maintain the average minimum temperature at Torrance Airport three to four degrees lower than at Los Angeles International Airport. The minimum temperatures at Torrance Airport can be considered as representative of

¹A comparison of Los Angeles Air Pollution Control District monitoring stations proves this to be the case.

FIGURE 9
CLIMATE ZONES IN TORRANCE

- Zone 1:** This is the climate along Southern California beaches that is almost completely dominated by the ocean. In Torrance, this zone roughly corresponds to the boundaries of the El Segundo Sand Hills. In this climate zone the winters are mild, the summers are cool and often of limited sunshine because of frequent low clouds and fog, and the air is seldom really dry.
- Zone 2:** This zone is under marine influence most of the time and has many of the characteristics as neighboring Zone 1. It enjoys somewhat more summer heat, however, and the relative humidity tends to be a little less. Winters are very mild and frosts are extremely rare because this area consists of the air-drained slopes of the Palos Verdes Hills.
- Zone 3:** This zone is influenced by the ocean approximately 85% of the time and is the cold winter portion of the coastal climate. In the Torrance area this zone occurs in the cold air drainage basin of eastern Torrance known as the Torrance Plain. Actually, the winters are so mild here that winter lows are not of much significance, although frosts occur more frequently than in Zones 1 or 2. Summer heat is comparable to that of Zone 2.



southeastern Torrance, as all of this area is under the influence of both the drainage wind and the Palos Verdes Hills onshore flow modification. The western portion of the City consists of air-drained slopes and would be better represented by Los Angeles International Airport. The northeast portion of the City is influenced by the drainage wind but not by the Palos Verdes Hills. Minimum temperatures for this area would be expected to approximate the minimum at Torrance Airport in the winter, while summer minimum temperatures would be better represented by Los Angeles International Airport.

Microclimate Zones Within Torrance

There are 13 distinct climate zones in Southern California of which 3 occur within the City of Torrance. For the most part the differences between adjacent climate zones are small, and this is especially true of the 3 zones in Torrance. However, the differences are not only measurable, but detectable without instrumentation by the interested observer.

A map delineating the climate zones in Torrance is included as Figure 9. Do not consider the lines on the map as rigid. The lines shift gradually back and forth as the strengths of the controlling factors rise and fall.

SUMMARY OF THE CLIMATE IN THE CITY OF TORRANCE

The City of Torrance lies entirely within the area of maximum marine influence called the maritime fringe. Marine air covers this area most of the year, but air from the interior reaches the coast at times, especially during the Fall and Winter months. The most characteristic feature of the coastal climate is the night and morning low cloudiness and sunny afternoons which prevail during the Spring and Summer months and occur often during the remainder of the year. Combined with the westerly sea breeze over Torrance, the coastal low cloudiness is associated with mild temperatures throughout the year. The daily temperature range is usually less than 20° in summer, increasing to approximately 25° in the Winter. Hot weather is not frequent at any season along the coast, although readings have exceeded 90° in Torrance in every month except January (89°) when air from the interior reached the coast. When high temperatures do occur, the humidity is almost always low so that discomfort is unusual. Nighttime temperatures are generally cool, but minimum temperatures average above 40° even in the coldest month (42° in January). Prevailing daytime winds are from the west, but night and early morning breezes are usually light and from the east and northeast. Daytime westerly flow is strongest in the Summer with the nighttime east wind better developed in the Winter. Strongest winds are from the west and north and are associated with Winter storms. At times during the Fall, Winter and Spring gusty, dry, northeasterly Santa Ana winds flow over Southern California mountains and through passes toward the coast. In Torrance these strong winds never reach the damaging velocities experienced further inland. However, the extremely dry air and dust clouds

associated with these winds can be expected over the City several times each year.

Precipitation occurs mainly in the cooler months with about 85% falling from November through April on the average. There is a marked variability in monthly and seasonal totals, with annual precipitation values ranging from 1/3 to 3 times normal values.

The visibility in Torrance is frequently restricted by haze, fog, or "smog". Low visibilities are favored by a layer of moist marine air trapped below warm dry air aloft. The zone of contact of the two unlike air masses is called the "temperature inversion", and prevents the water vapor and pollutants in the marine layer from dispersing into the atmosphere. Light fog occurs at sometime nearly every month, but heavy fog is observed least during the Summer while light fog is more common at this time. The generally clear skies, onshore flow, and strong temperature inversion make the late Summer a favored time for heavy photochemical smog over the Los Angeles Basin. Along the coast, the persistent westerly winds tend to minimize smog build-up. However, primary contaminants do present a problem.

Generally the City of Torrance can be said to be free of the temperature extremes and violent weather associated with interior, midlatitude locations. The area has sparse rainfall, high humidity and fog and low clouds in the night and morning hours much of the year. Still the amount of sunlight received in Torrance compares favorably with most midlatitude locations, and the climate here is one of the most equable in the world.

TABLE 1
CLIMATIC SUMMARY FOR TORRANCE

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Absolute Maximum Temperature (°F)	89	92	92	97	97	97	100	96	111	105	98	94	111
Mean Maximum Temperature (°F)	65	65	67	69	71	73	77	77	77	75	73	68	71
Mean Daily Temperature (°F)	53	54	56	59	61	64	68	68	67	64	59	55	61
Mean Minimum Temperature (°F)	42	44	45	49	52	56	59	60	58	54	47	44	51
Absolute Minimum Temperature (°F)	24	28	31	28	37	43	46	47	43	35	29	29	24
Mean Number of Days Temperature Equal to or Greater Than 90°F													8.8
Mean Number of Days Temperature Equal to or Less Than 32°F													3.6
Mean Relative Humidity (%)	72	69	71	72	71	73	73	74	73	72	65	67	71
Mean Precipitation (inches)	2.69	2.90	1.87	0.90	0.10	0.06	0.00	0.01	0.25	0.37	0.82	2.21	12.2
Mean Number of Days With Precipitation Equal or Greater Than 0.1 Inch	5.7	6.0	4.6	2.5	0.1	0.4	0.0	0.3	1.3	1.4	2.0	5.0	29.3
Mean Number of Days With Occurrence of Visibility Less Than ½ Mile	7.5	5.3	5.9	4.4	1.6	2.1	2.6	4.7	6.9	7.2	7.7	8.4	64.3
Mean Number of Days With Occurrence of Ceiling* Less Than 1,500 Feet and/or Visibility Less Than 3 Miles	11.7	9.7	11.5	11.2	9.8	16.4	17.4	18.5	16.6	16.8	13.2	11.8	162.8
Mean Number of Days With Occurrence of Thunderstorm(s)													2.0

*Ceiling is defined as ½ or greater of sky covered by clouds.

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George B. Surber, councilman
William J. Uerkwitz, councilman
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